

CHP 101 and Opportunities

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Outline

CHP 101

- What is CHP and Benefits?
- Technical Potential for CHP in Kentucky
- Case Studies
- Barriers to CHP

Win-Win Strategies for CHP

- Technical Assistance
- Opportunities

Next Steps

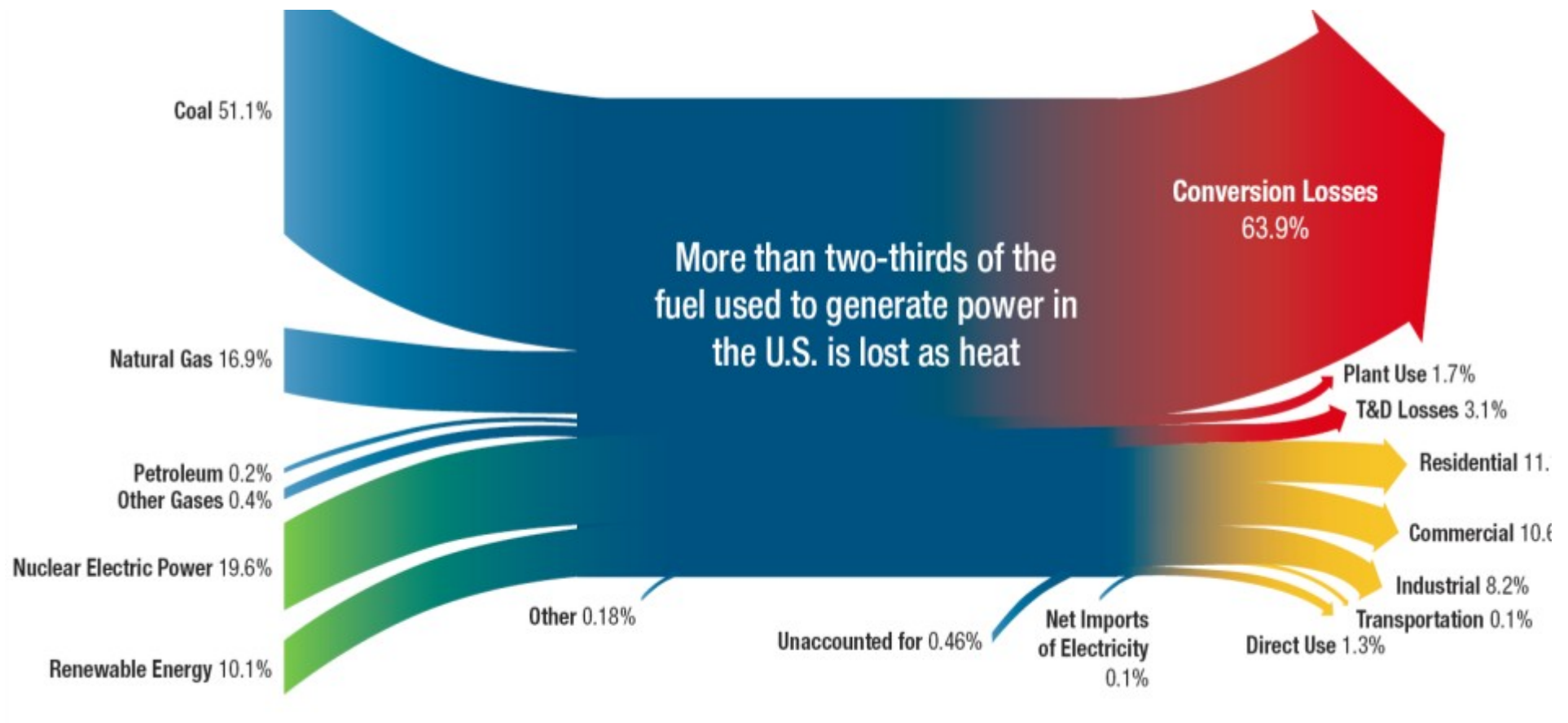
What Is Combined Heat and Power?

CHP is an *integrated energy system* that:

- Is located at or near a factory or building
- Generates electrical and/or mechanical power
- Recovers waste heat for
 - heating,
 - cooling or
 - dehumidification
- Can utilize a variety of technologies and fuels



Fuel Utilization by U.S. Utility Sector



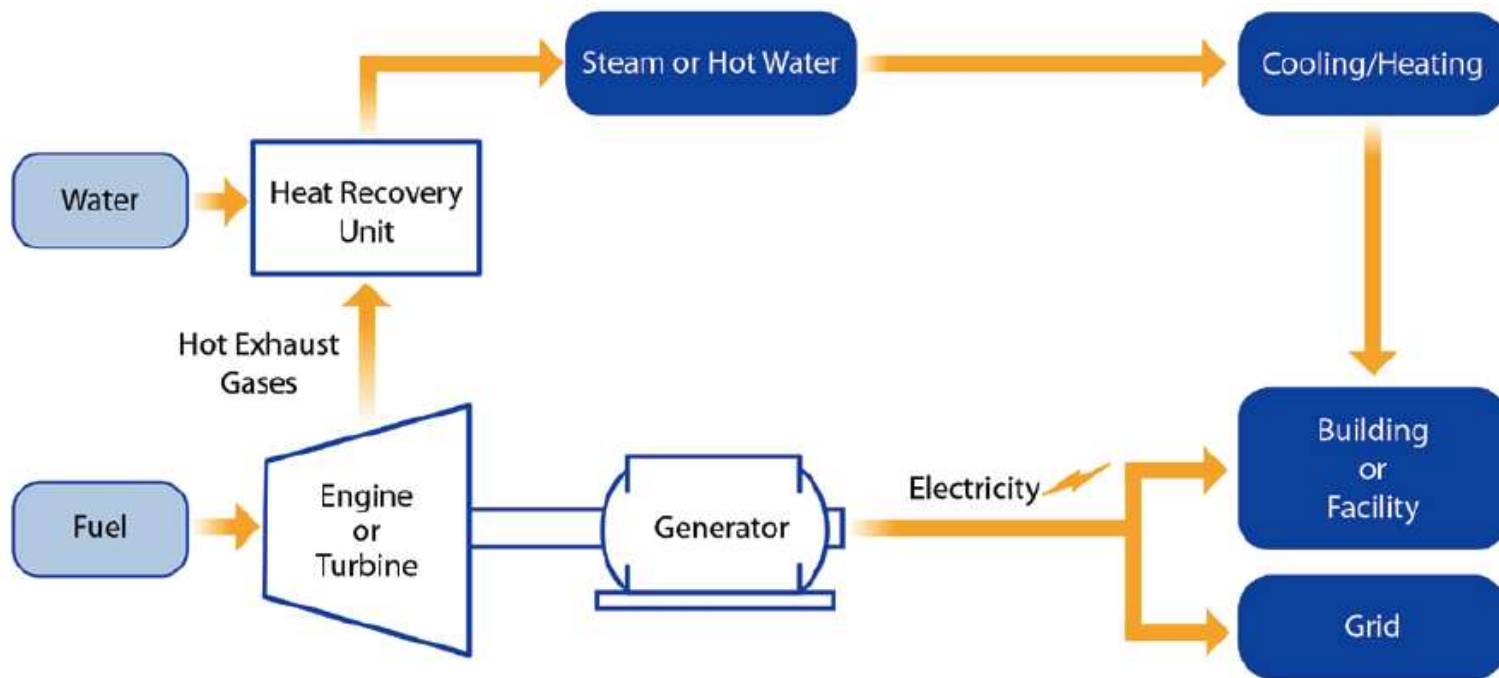
Source: http://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_report_12-08.pdf

Defining Combined Heat & Power (CHP)

*The on-site simultaneous generation of two forms of energy
(heat and electricity) from a single fuel/energy source*

Conventional CHP

(also referred to as Topping Cycle CHP or Direct Fired CHP)



Separate Energy Delivery:

- Electric generation – 33%
- Thermal generation - 80%
- Combined efficiency – 45% to 55%

CHP Energy Efficiency (combined heat and power)
70% to 85%

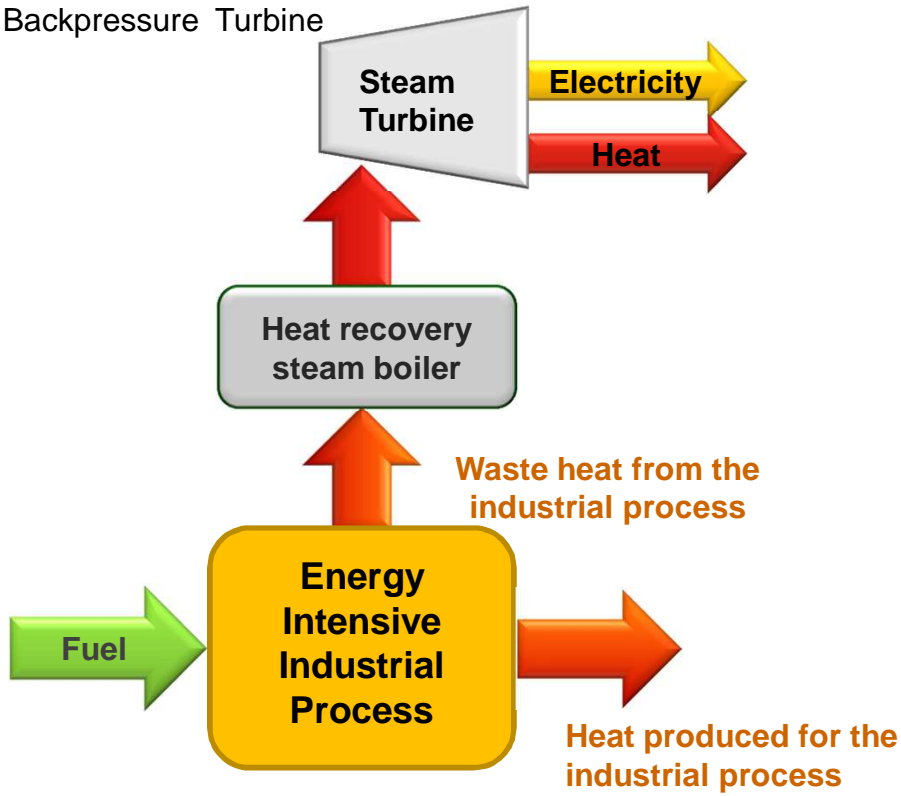
Defining Combined Heat & Power (CHP)

*The on-site simultaneous generation of two forms of energy
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Waste Heat to Power CHP

(also referred to as Bottoming Cycle CHP or Indirect Fired CHP)

HRSG/Steam Turbine
Organic Rankine Cycle
Backpressure Turbine



- Fuel first applied to produce useful thermal energy for the process
- Waste heat is utilized to produce electricity and possibly additional thermal energy for the process
- Simultaneous generation of heat and electricity
- No additional fossil fuel combustion (*no incremental emissions*)
- Normally produces larger amounts electric generation (*often exports electricity to the grid; base load electric power*)

What Are the Benefits of CHP?

- CHP is more efficient than separate generation of electricity and heat
- Higher efficiency translates to lower operating cost, (but requires capital investment)
- Higher efficiency reduces emissions of all pollutants
- CHP can also increase energy reliability and enhance power quality
- On-site electric generation reduces grid congestion and avoids distribution costs

Attractive CHP Markets



Industrial

- Chemical manufacturing
- Ethanol
- Food processing
- Natural gas pipelines
- Petrochemicals
- Pharmaceuticals
- Pulp and paper
- Refining
- Rubber and plastics



Commercial

- Data centers
- Hotels and casinos
- Multi-family housing
- Laundries
- Apartments
- Office buildings
- Refrigerated warehouses
- Restaurants
- Supermarkets
- Green buildings



Institutional

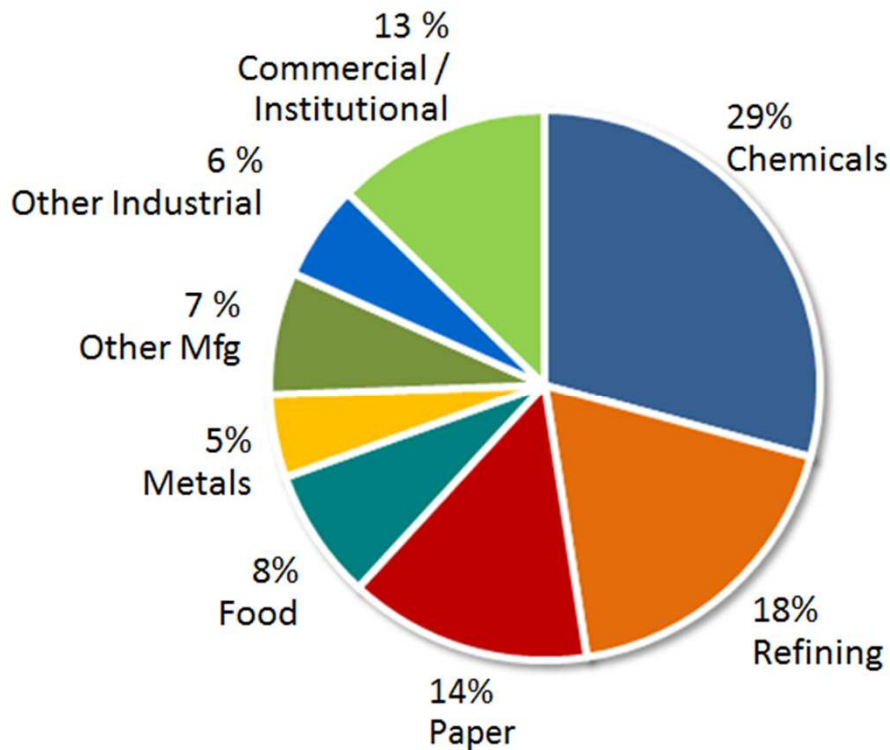
- Hospitals
- Schools (K – 12)
- Universities & colleges
- Wastewater treatment
- Residential confinement



Agricultural

- Concentrated animal feeding operations
- Dairies
- Wood waste (biomass)

CHP Today



Source: ICF CHP Installation Database, 2012 Data

- **82.4 GW** of installed CHP over 4,200 industrial and commercial facilities (2012)
- 87% of capacity in industrial applications
- 71% of capacity is natural gas fired
- Avoids more than **1.8 quadrillion Btus** of fuel consumption annually
- Avoids **241 million metric tons of CO₂** compared to separate production

CHP Is Used at the Point of Demand

**4,200 CHP Sites
(2012)**

**82,400 MW –
installed capacity**

**Saves 1.8 quads of
fuel each year**

**Avoids 241 M metric
tons of CO₂ each year**

87% of capacity – industrial

**71% of capacity – natural
gas fired**

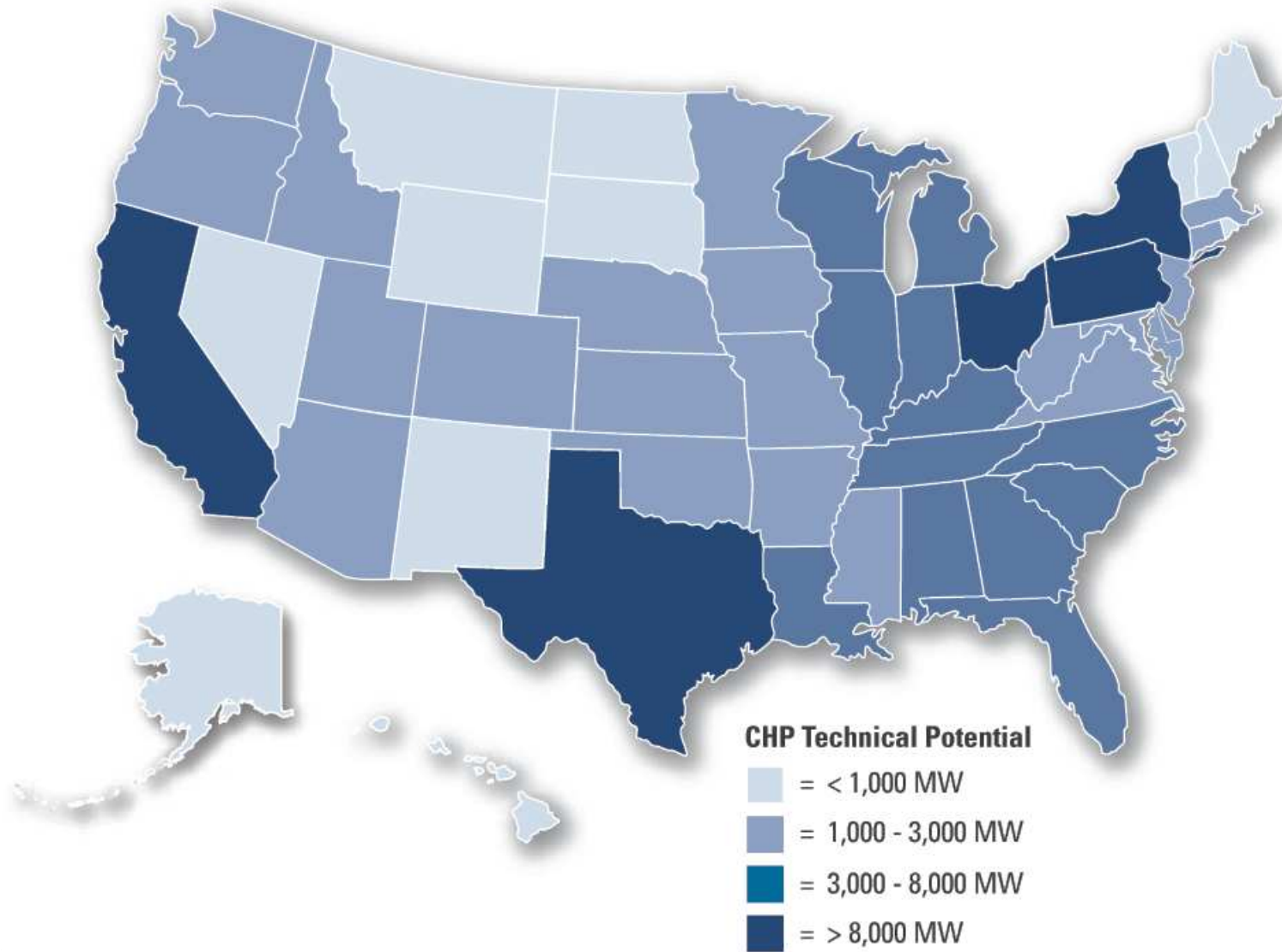


Existing CHP Systems in Kentucky

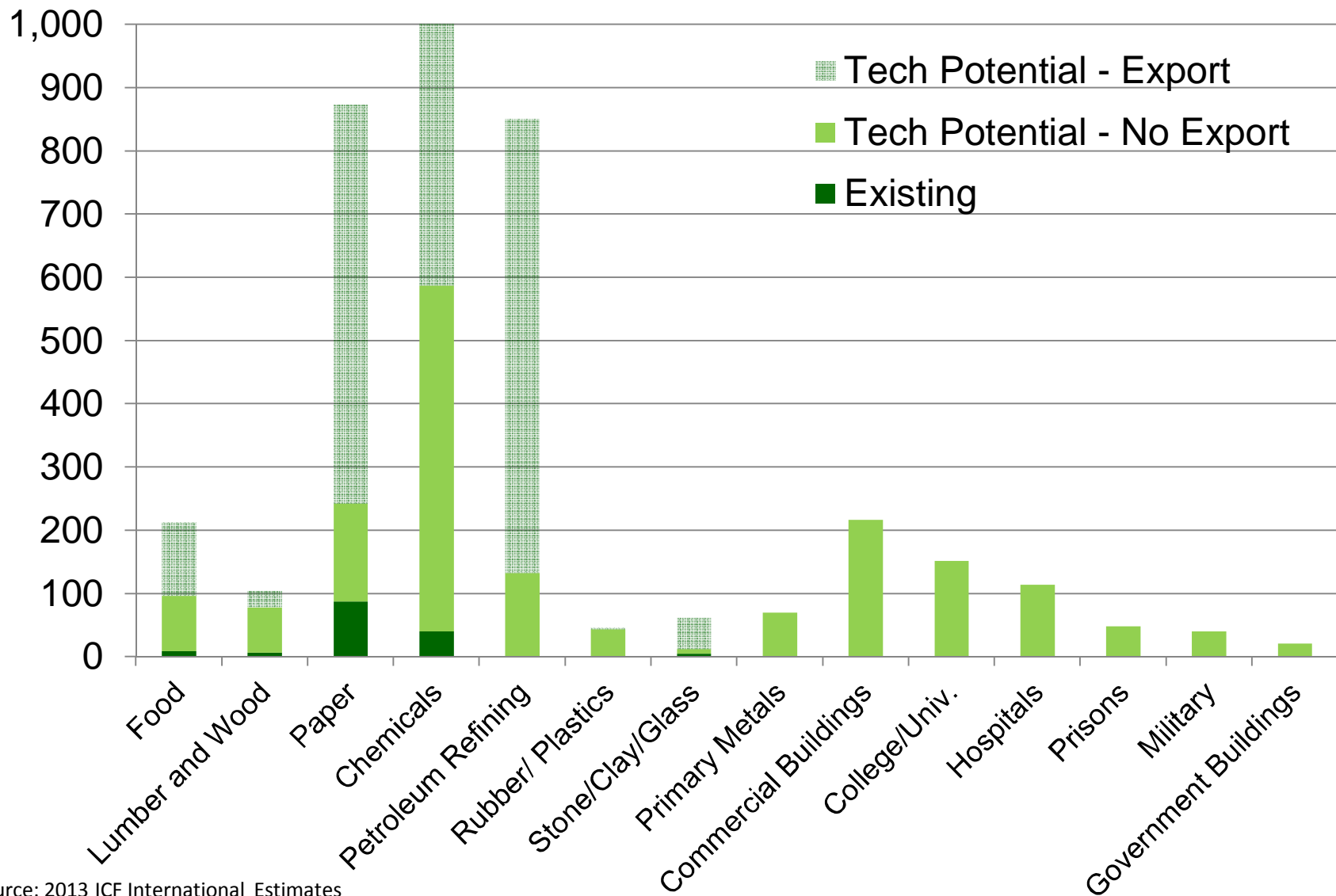
SIC Code	Company/Site	City	Year Open	Capacity (MW)	Technology	Fuel
24	Cox Interior Inc.	Campbellsville	1994	5.2	Boiler/Steam Turbine	Biomass
24	Domtar	Hawesville	2001	88	Boiler/Steam Turbine	Biomass
24	Cox Lumber	Campbellsville	2002	1	Waste Heat Recovery	Waste Heat
24	Young Manufacturing Company	Beaver Dam	1988	0.32	Waste Heat Recovery	Waste Heat
28	Air Products & Chemicals, Inc.	Calvert City	2000	23	Combustion Cycle	Natural Gas
31	Owensboro Grain	Owensboro	2013	9	Reciprocating Engine	Natural Gas
32	Continental Building Products	Silver Grove	2001	5.2	Combustion Cycle	Natural Gas
65	Western Kentucky Gas Company	Owensboro	1966	0.4	Reciprocating Engine	Natural Gas

Source: 2013 ICF International Database for ORNL

CHP Technical Potential is Nationwide



Existing and Technical Potential for CHP in Kentucky



Source: 2013 ICF International Estimates

CHP Case Studies

- CHP is not always sold on economics alone
- Multiple fuel sources can be used
- Heat can be used for multiple purposes
- Case Studies (Project Profiles) located at http://www1.eere.energy.gov/manufacturing/distributedenergy/projects_sector.html#healthcare

Young Manufacturing – 320 kW

- Steam was initially present for mill processes
- 2 steam turbines were installed to be powered by excess heat from steam boilers
 - 120 kW
 - 200 kW
- Boilers are fueled by mill waste

Biomass Boiler



Generator (200 kW) and turbine



US Army Retail Center– 2 MW

- 2.0 MW Lean Burn Reciprocating Natural Gas Generator
- Exhaust recovery produces chilled water
- 495 tons of absorption cooling
- Hot water recovery from engine produces 6.5 MMBtu/hr
- BACT significantly reduces emissions versus traditional system



NG Generator (2 MW) with BACT

US Army Data Center– 2 MW

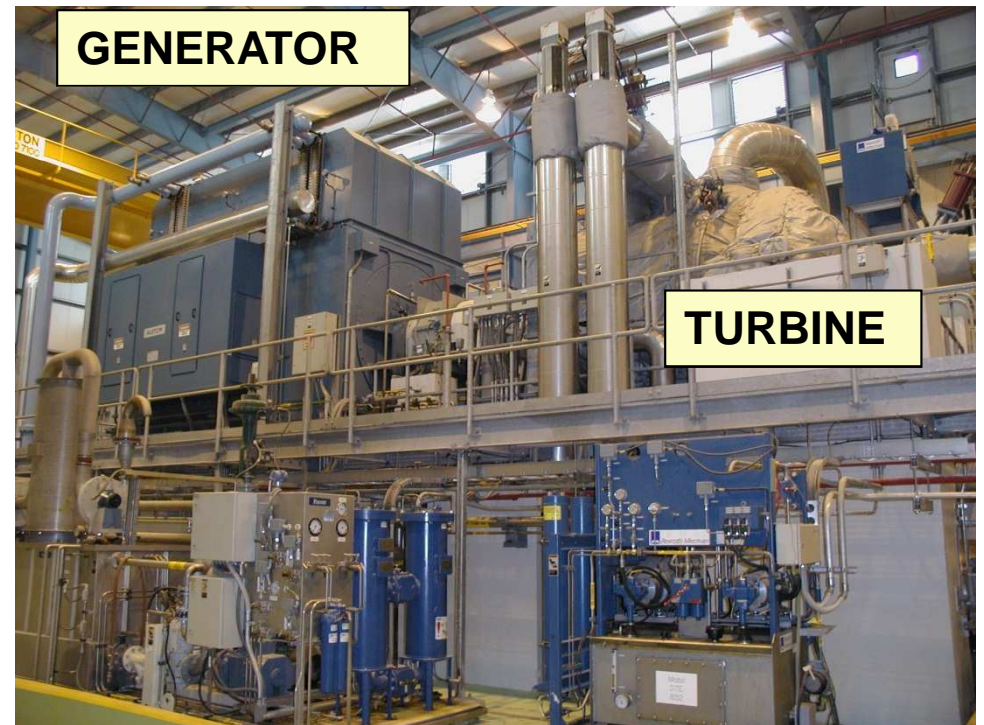
- 2.0 MW Lean Burn Reciprocating Natural Gas Generator
- Exhaust and Hot water recovery produces chilled water
- 705 tons of absorption cooling serves data center CRAC units
- **CHP system serves both day-to-day and emergency power**



*705 ton Absorption Chiller –
Exhaust and Hot water driven*

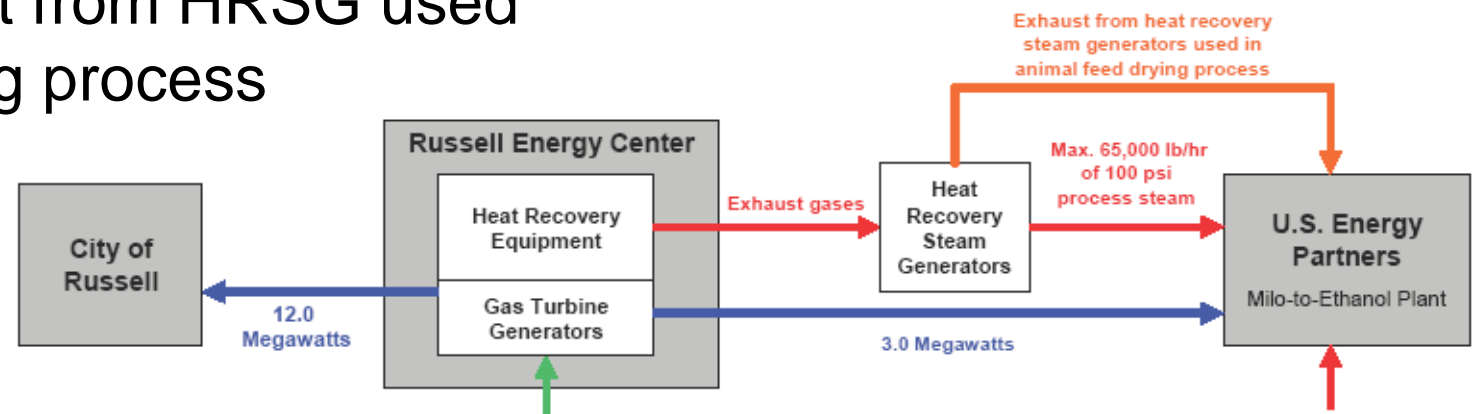
Domtar-Hawesville – 65 MW

- Steam produced by burning waste pulp liquor and wood biomass
- High pressure steam used to power turbine
- Turbine generates electricity at 12.47 kV
- Remaining steam used in industrial process
- 70% of plant power produced onsite



Russell, KS Municipal Partnership – 15 MW

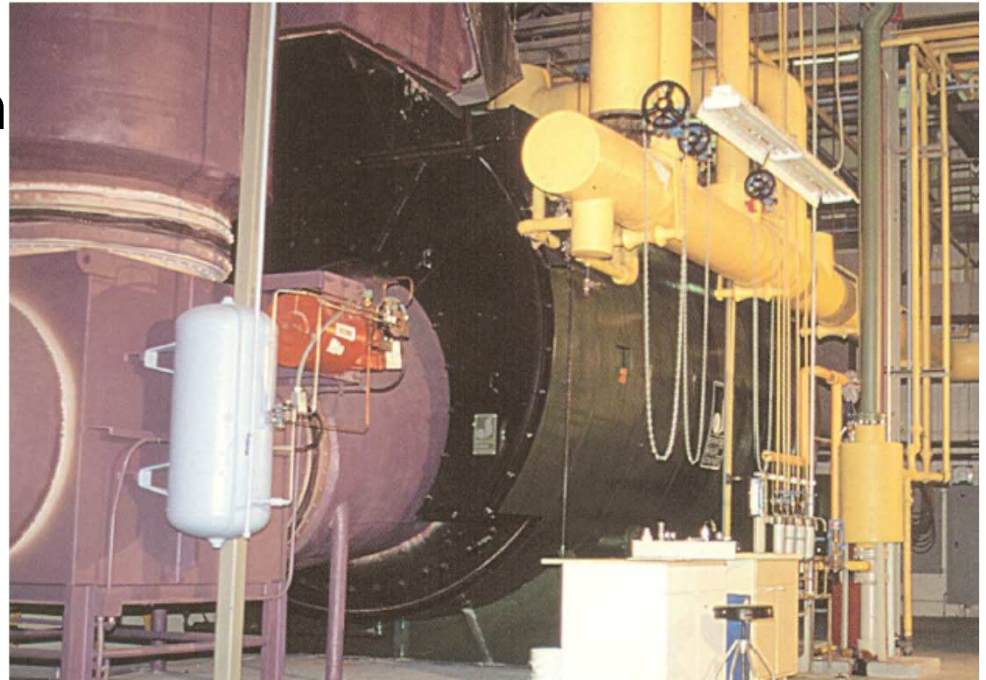
- (2) 7.5 MW combustion turbines
- Fuel by natural gas
- Heat recovery steam generators (HRSG) provides 65,000 lb/hr steam
- Exhaust from HRSG used in drying process



Source: <http://www.midwestchptap.org/profiles/ProjectProfiles/USEnergyPartners.pdf>

US Army Hospital – 4 MW

- 4.0 MW Lean Burn Reciprocating Natural Gas Generator
- Exhaust recovery produces 7,600 lb/hr of medium pressure steam
- 640 tons of absorption cooling produced from hot water recovery
- Installed to create fully redundant heat, chilled water, and power production for hospital



Waste heat boiler – Exhaust driven

University of Cincinnati – 47 MW

- District Heating and Cooling serving 6 hospitals and entire university
- Natural Gas Turbines and steam turbine
- 610,000 lb/hr peak steam production capacity
- 3,400 tons of absorption cooling available
- Matches grid electric reliability rating of 99.98%



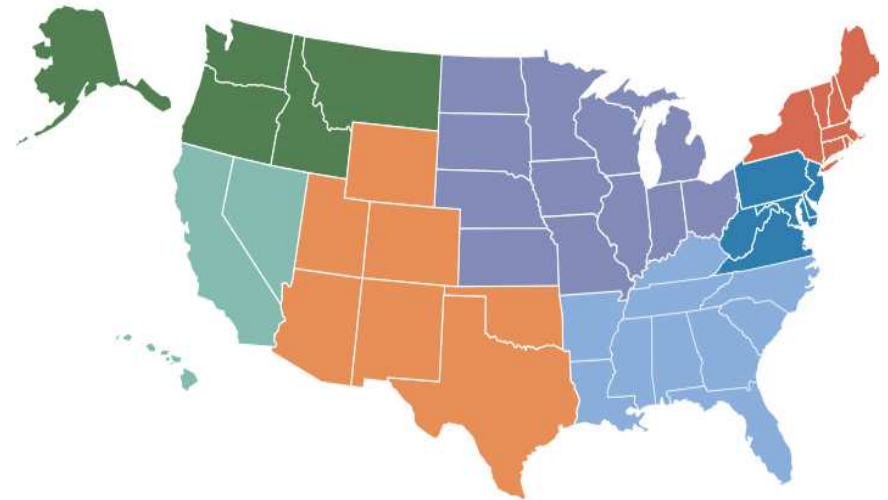
A Number of Prominent Barriers to CHP

- Large Capital Investment which many companies are not ready to make
 - Long payback periods by their standards
 - Not directly related to their main area of business
- Discouraged by many electric utilities
 - Utility regulatory framework often does not encourage CHP and there is poor understanding of risks/rewards
 - Utilities encouraged to invest in central station power and upgrading the present grid structure (larger rates of return on their investments)
- Increases site emissions while reducing overall
 - No credit given for emissions reduction from power plants

CHP Technical Assistance Partnerships

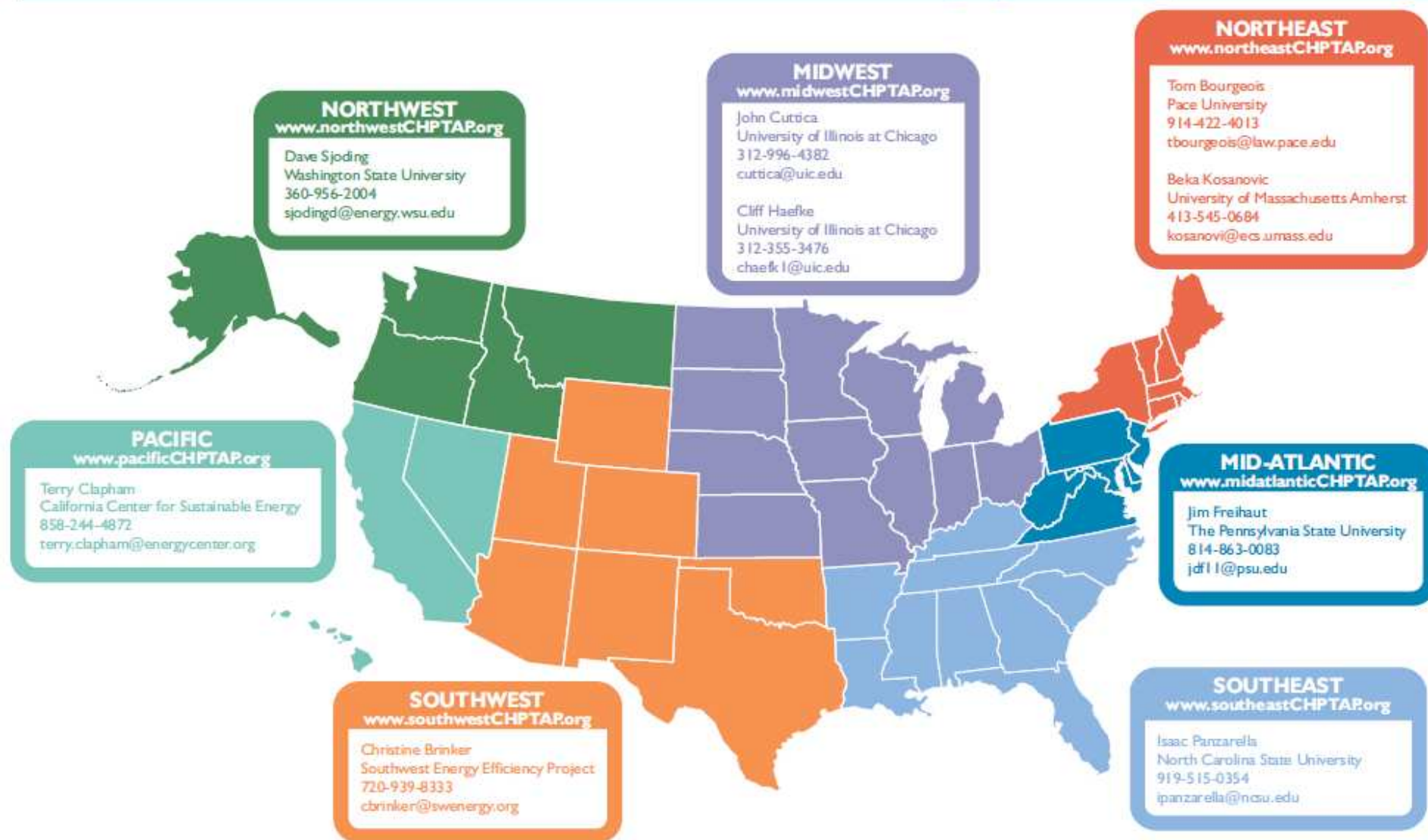
Key Activities

- **Market Opportunity Analysis.**
Supporting analyses of CHP market opportunities in diverse markets including industrial, federal, institutional, and commercial sectors
- **Education and Outreach.**
Providing information on the energy and non-energy benefits and applications of CHP to state and local policy makers, regulators, end users, trade associations, and others.
- **Technical Assistance.**
Providing technical assistance to end-users and stakeholders to help them consider CHP, waste heat to power, and/or district energy with CHP in their facility and to help them through the development process from initial CHP screening to installation.



<http://eere.energy.gov/manufacturing/distributedenergy/chptaps.html>

DOE CHP Technical Assistance Partnerships (CHP TAPs)



DOE CHP Technical Assistance Partnerships (TAPs): Program Contacts

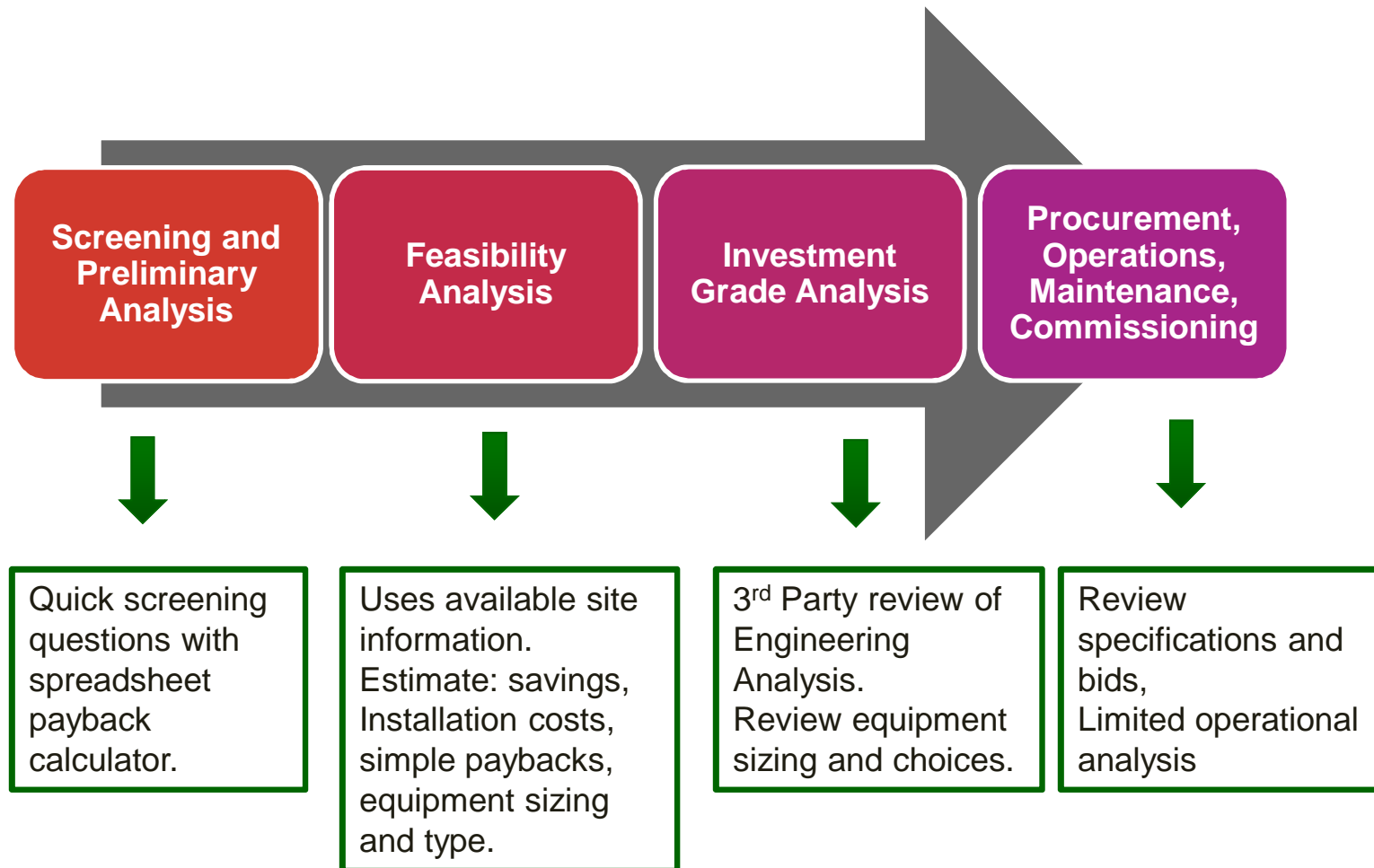
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CHP TAP Technical Development Assistance



CHP TAP CHP Qualification Screening Example

CHP TAP CHP Qualification Screen

Gas Fueled CHP - Recip Engine, Microturbine, Fuel Cell or Gas Turbine Systems / natural gas, LFG, biogas

Facility Information

Facility Name

ABC Health Care

Location (City, State)

Anywhere, USA

Application

Hospital

Annual Hours of Operation

8520

Annual operating hours with loads conducive to CHP

Average Power Demand, MW

10.4

Annual Electricity Consumption, kWh

88,250,160

Average Thermal Demand, MMBtu/hr

50

Annual Thermal Demand, MMBtu

426,000

Thermal Fuel Costs, \$/MMBtu

\$6.00

CHP Fuel Costs, \$MM/Btu

\$6.00

Average Electricity Costs, \$/kWh

\$0.080

Percent Electric Price Avoided

90%

Typically 70 to 95%

CHP System

Net CHP Power, MW

10.2

Based on thermal match but capped at average power demand

CHP Electric Efficiency, % (HHV)

29.1%

CHP system specs

CHP Thermal Output, Btu/kWh

4,922

CHP system specs

CHP Power to Heat Ratio

0.69

Calculated based on CHP power output and thermal output

CHP Availability, %

96%

90 to 98%

Incremental O&M Costs, \$/kWh

\$0.009

CHP system specs

Displaced Thermal Efficiency, %

80.0%

Displaced onsite thermal (boiler, heater, etc) efficiency

Thermal Utilization, %

100.0%

Amount of available thermal captured and used - typically 80 to 100%

CHP Qualification Screening Example, Continued

Annual Energy Consumption

Purchased Electricity, kWh
Generated Electricity, kWh
On-site Thermal, MMBtu
CHP Thermal, MMBtu
Boiler Fuel, MMBtu
CHP Fuel, MMBtu
Total Fuel, MMBtu

Base Case

88,250,160
0
426,000
0
532,500
0
532,500

CHP Case

5,534,150
82,716,010
18,872
407,128
23,590
969,845
993,435

Annual Operating Costs

Purchased Electricity, \$
On-site Thermal Fuel, \$
CHP Fuel, \$
Incremental O&M, \$
Total Operating Costs, \$

\$7,060,013
\$3,195,000
\$0
\$0
\$10,255,013

\$1,104,460
\$141,539
\$5,819,071
\$744,444
\$7,809,514

Simple Payback

Annual Operating Savings, \$
Total Installed Costs, \$/kW
Total Installed Costs, \$/k
Simple Payback, Years

\$2,445,499
\$1,400
\$14,221,861
5.8

Operating Costs to Generate

Fuel Costs, \$/kWh
Thermal Credit, \$/kWh
Incremental O&M, \$/kWh

\$0.070
(\$0.037)
\$0.009

Total Operating Costs to Generate, \$/kWh

\$0.042

Feasibility Analysis

A DOE CHP TAP Feasibility Analysis Usually Involves

- Baseline Energy Analysis
 - Electrical load profiling
 - Thermal load profiling
- CHP Equipment Selection and Sizing
 - Matching technology to thermal needs, size, fuel availability, and unique requirements (duct firing, thermal, reliability considerations)
- Analysis Assumptions
 - Energy Costs – electric rates and fuel prices
 - CHP System Costs – installed equipment costs, O&M, interconnection

Feasibility Considerations, Continued

- Feasibility Analysis
 - Facility Energy Profiles on baseline and CHP Options
 - Economic Analysis – operating savings, payback/IRR/ROI
 - Sensitivity Analysis
 - Emissions Analysis
- Recommended Next Steps

Feasibility Considerations, Continued

- Feasibility Analysis
 - Facility Energy Profiles on baseline and CHP Options
 - Economic Analysis – operating savings, payback/IRR/ROI
 - Sensitivity Analysis
 - Emissions Analysis
- Recommended Next Steps

State Energy Efficiency Action Network: Guide to the Successful Implementation of State Combined Heat and Power Policies

DOE/EE-0838



Guide to the Successful Implementation of State Combined Heat and Power Policies

Industrial Energy Efficiency and Combined Heat and Power
Working Group

Driving Ratepayer-Funded Efficiency through Regulatory
Policies Working Group

March 2013

The State and Local Energy Efficiency Action Network is a state and local effort facilitated by the federal government that helps states, utilities, and other local stakeholders take energy efficiency to scale and achieve all cost-effective energy efficiency by 2020.

Learn more at www.seeaction.energy.gov

Discusses five policy categories and highlights successful state CHP implementation approaches within each category:

- Design of standby rates
- Interconnection standards for CHP with no electricity export
- Excess power sales
- Clean energy portfolio standards (CEPS)
- Emerging market opportunities—CHP in critical infrastructure and utility participation in CHP markets.

State and Local Energy Efficiency Action Network. 2013. *Guide to the Successful Implementation of State Combined Heat and Power Policies*. Prepared by B. Hedman, A. Hampson, J. Rackley, E. Wong, ICF International; L. Schwartz and D. Lamont, Regulatory Assistance Project; T. Woolf, Synapse Energy Economics; J. Selecky, Brubaker & Associates. http://www1.eere.energy.gov/seeaction/pdfs/see_action_chp_policies_guide.pdf

Standby Rates for CHP

Utility tariffs for “standby rates” or “partial requirements service”—the set of retail electric products for customers with on-site, non-emergency generation can reduce the cost savings for CHP to a uneconomical point.

The tariffs are meant to recover the utility costs of providing backup power, but cover other services:

- *Backup power* during an unplanned generator outage
- *Maintenance power* during scheduled generator service for routine maintenance and repair
- *Supplemental power* for customers whose on-site generation under normal operation does not meet all of their energy needs, typically provided under the full requirements tariff for the customer’s rate class
- *Economic replacement power* when it costs less than on-site generation
- *Delivery* associated with these energy services.

Typically, standby rates are “ratcheted” to customer’s peak demand for an entire year, and charges do not reflect actual costs, especially for CHP customers with low forced outage rates.

Standby Rate Barrier Example: Iowa

- The Midwest CEAC published a 2011 study, “Iowa On-site Generation Tariff Barrier Overview”
- Avoided rates for self-generation customers as a percentage of retail rates under tariffs for four utilities ranged from 71.9% to 80.5%.
- Modeling for CHP on Mid-American Eastern
 - 1.6 MW CHP generating 81% of required kWh onsite
 - avoids 74.7% of average retail service rate
 - resulting in a savings of only 61% for CHP
 - 41% of charges attributable to standby service

Standby Rate Barrier Example: Iowa

Mid-American Eastern System	Full Requirements*	Partial Requirements
Energy Purchased(kWh)	16,660,800 kWh	3,034,644 kWh
Portion Backup Energy		151,536 kWh
Portion Maintenance Energy		46,308 kWh
Facilities Charge	\$240.00	\$240.00
Demand Charges	\$241,232.50	\$134,740.00
Energy Charges	\$566,813.50	\$188,002.04
Standby Charges	n/a	n/a
AEP Cost Recovery	\$3,665.38	\$667.62
Energy Efficiency Cost Recovery	\$37,820.02	\$6,888.64
Total Charges	\$849,771.39	\$330,538.30
kWh Difference	13,626,156 kWh	
Monetary Difference	\$519,233.09	
Average rate for purchased power	\$0.05100	\$0.10892
Average avoided rate		\$0.03811
Avioded rate as a percentage of average retail service rate	74.71%	

Improved Standby Rate Design for CHP

Utility standby tariffs incorporating the following features could encourage CHP self-generators to use electric service most efficiently and more accurately charge them for actual costs of standby service:

- Offer daily or monthly as-used demand charges for backup power and shared transmission and distribution (T&D) facilities
- Reflect load diversity of CHP customers in charges for shared delivery facilities
- Provide an opportunity to purchase economic replacement power
- Allow customer-generators the option to buy all of their backup power at market prices
- Allow the customer to provide the utility with a load reduction plan
- Offer a self-supply option for reserves.

DSIRE™

Database of State Incentives for Renewables & Efficiency

U.S. DEPARTMENT OF
ENERGY

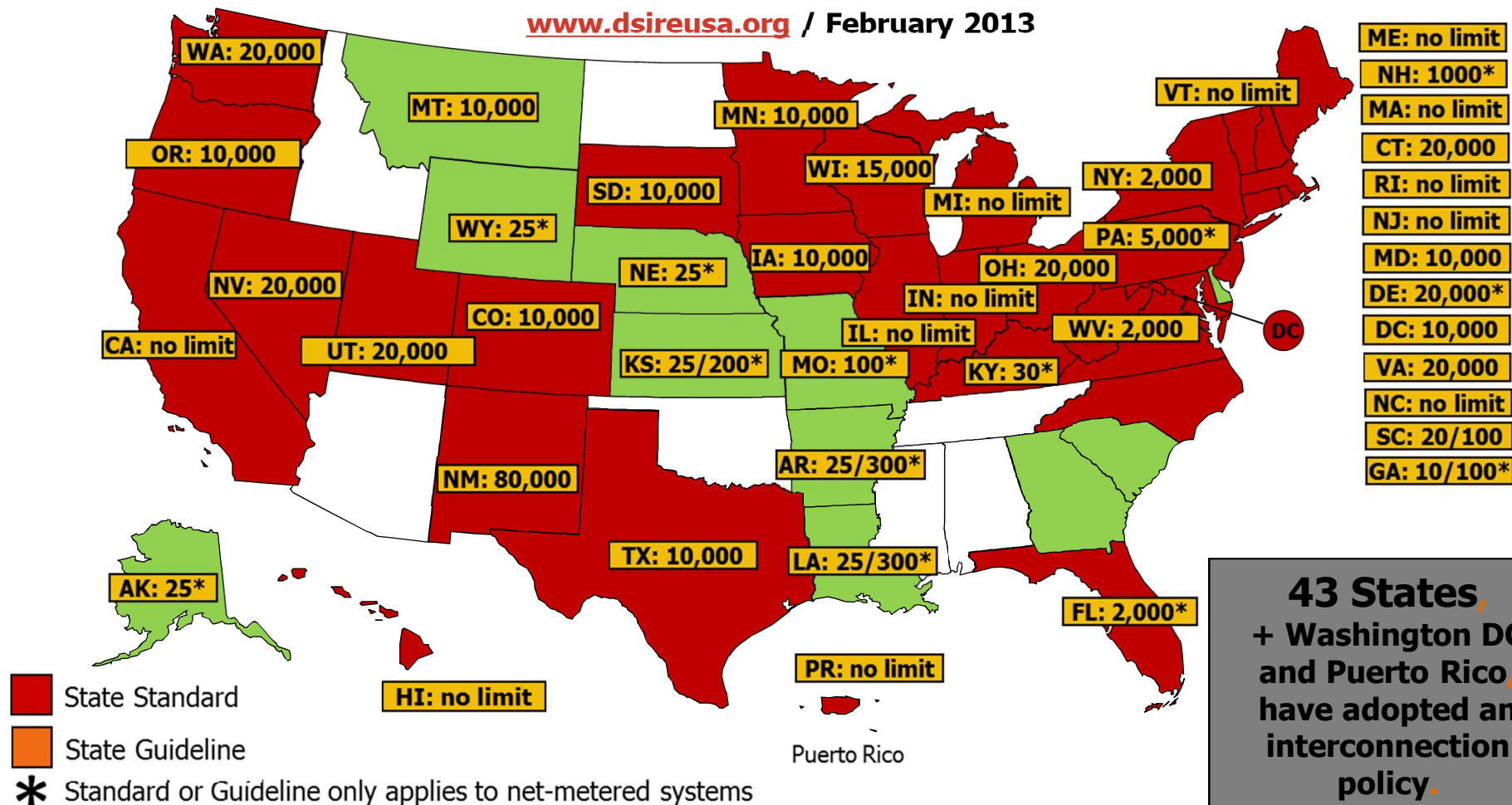
Energy Efficiency &
Renewable Energy

IREC
INTERSTATE RENEWABLE ENERGY COUNCIL

**NORTH CAROLINA
Solar Center**

Interconnection Policies

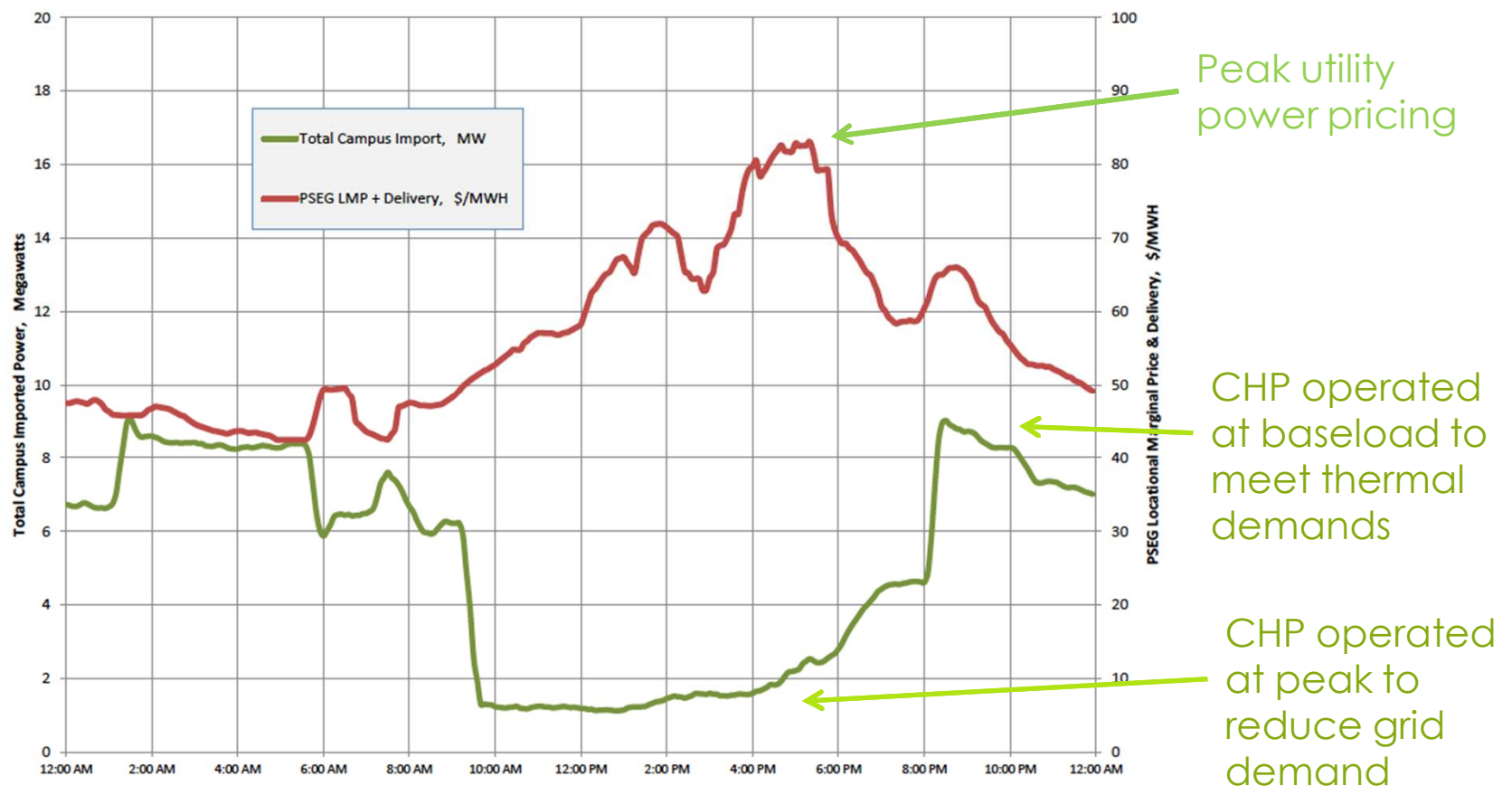
www.dsireusa.org / February 2013



Notes: Numbers indicate system capacity limit in kW. Some state limits vary by customer type (e.g., residential versus non-residential). "No limit" means that there is no stated maximum size for individual systems. Other limits may apply. Generally, state interconnection standards apply only to investor-owned utilities.

Real time pricing offers a win-win CHP strategy

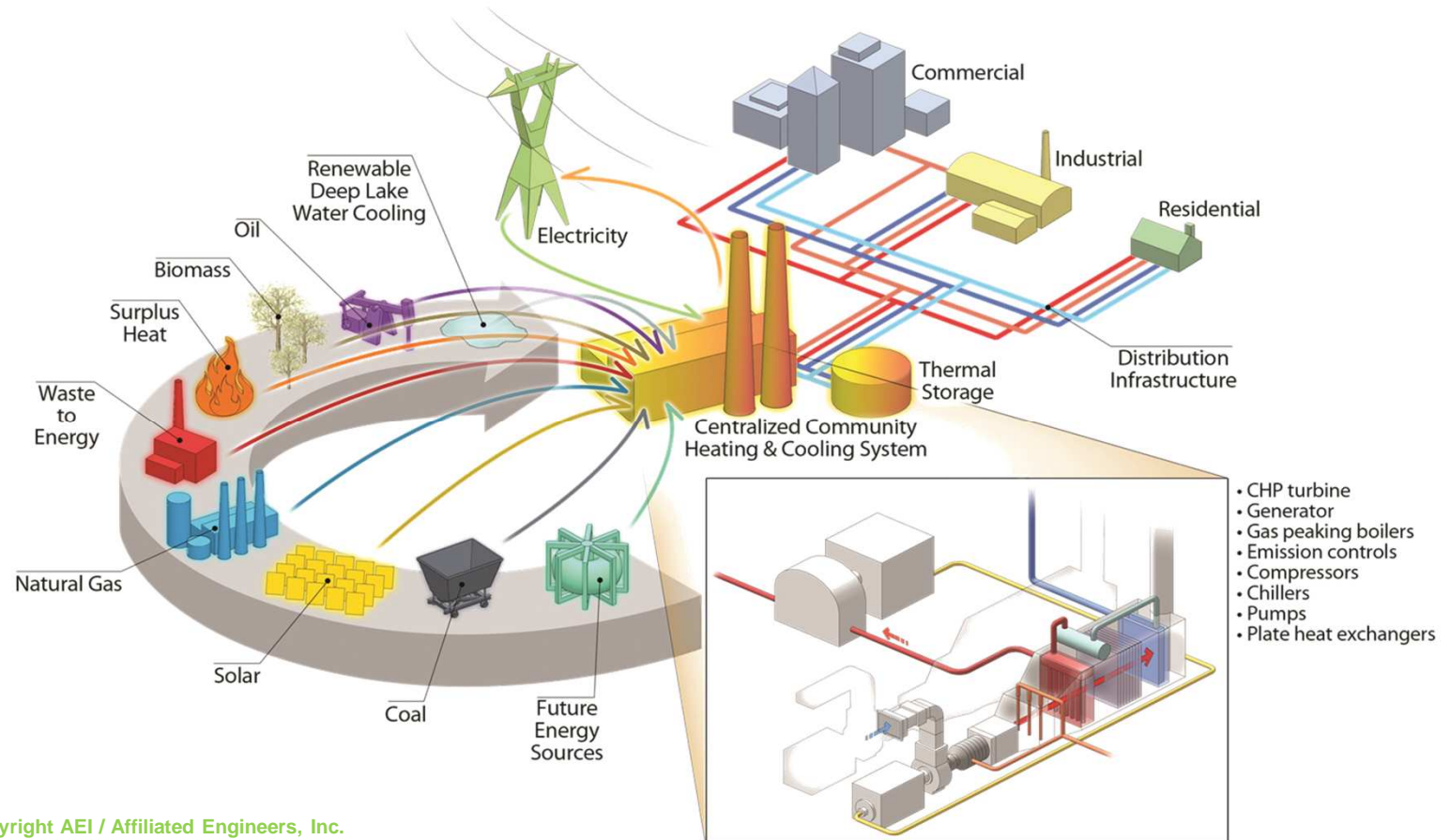
- Princeton University has a 15 MW gas turbine CHP system, operated to maximize savings by reducing demand on grid during peak pricing times.



Borer, "Ted Talk on CHP & Campus Sustainability" for International District Energy Association. February 2013;
<http://www.districtenergy.org/26th-annual-campus-energy->

CHP with District Energy & Microgrids

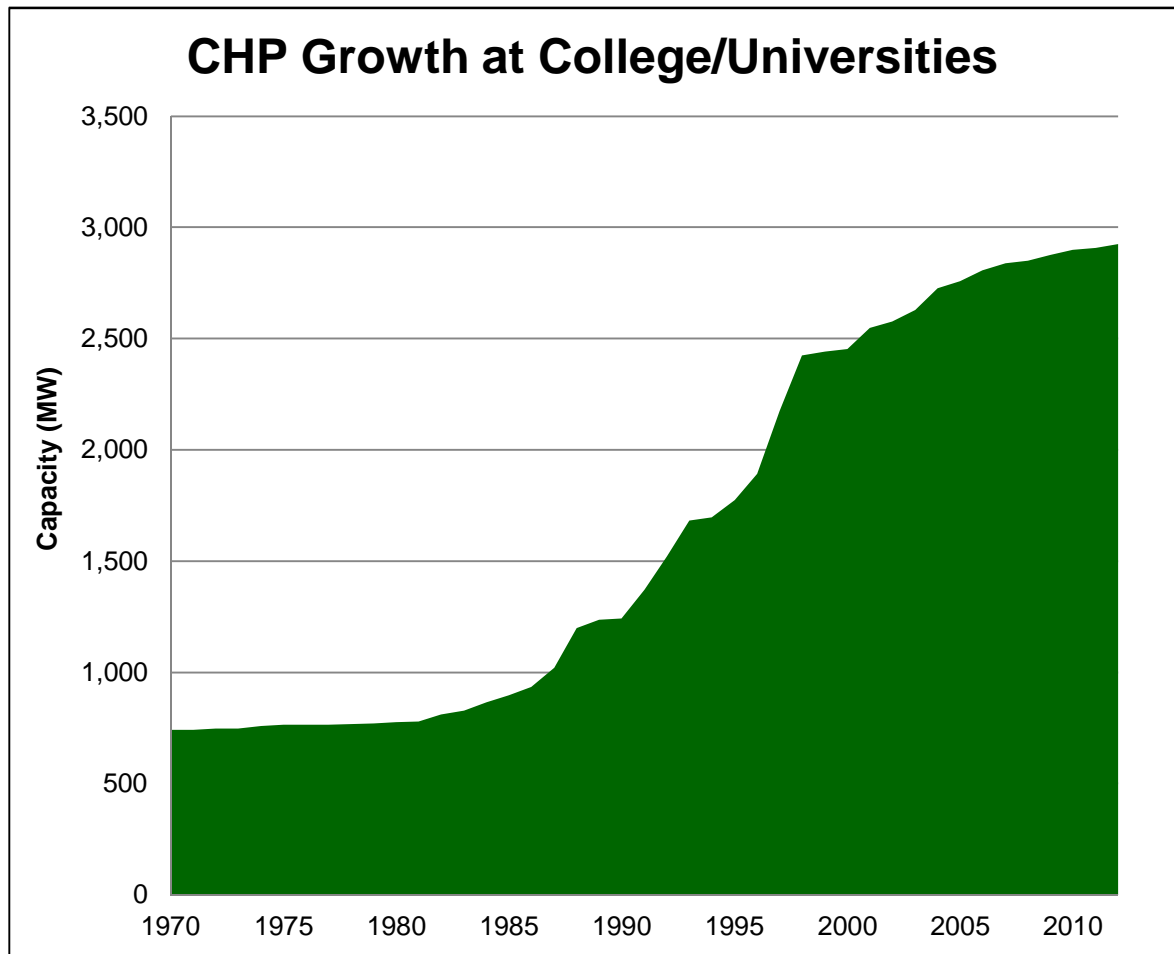
- Local “distributed” generation integrating CHP; thermal energy; electricity generation; thermal storage and renewables
- Able to “island” in the event of a grid failure



Illustration, copyright AEI / Affiliated Engineers, Inc.

CHP in Colleges & Universities

- 285 colleges and universities have CHP, totaling 2,714 MW of capacity.
- Represents 3.3% of total installed CHP capacity in the U.S. (82 GW)
- Further technical potential totaling 8,403.9 MW of capacity



Source: ICF CHP Technical Potential Database

CHP and Critical Infrastructure

“Critical infrastructure” refers to those assets, systems, and networks that, if incapacitated, would have a substantial negative impact on national security, national economic security, or national public health and safety.”



Applications:

- Hospitals and healthcare centers
- Water / wastewater treatment plants
- Police, fire, and public safety
- Centers of refuge (often schools or universities)
- Military/National Security
- Food distribution facilities
- Telecom and data centers

Thank you!

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